Overview of Modeling to Evaluate Risk and Maximize Predictability at Complex Sites

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Pacific Northwest National Laboratory,

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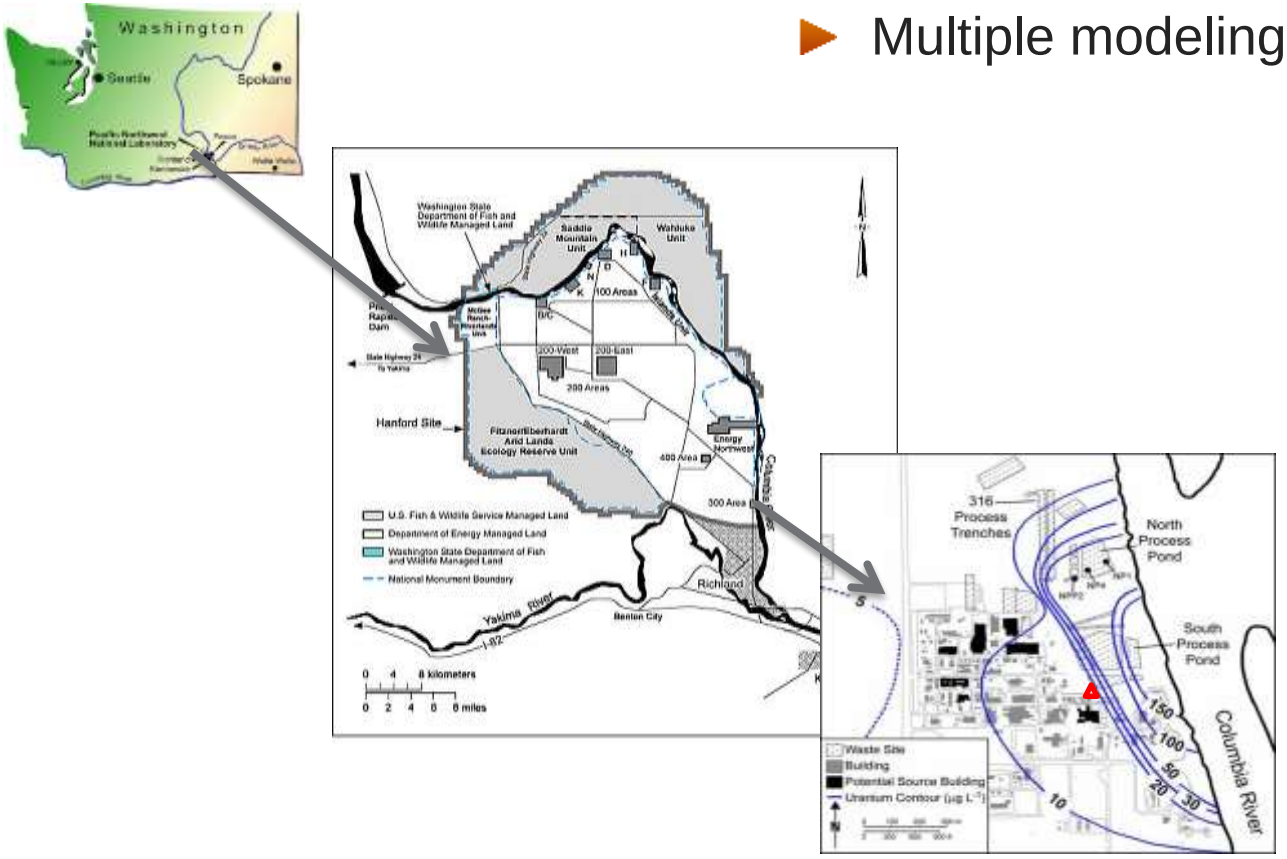
Hanford Site 300 Area

- Persistent uranium plume
- Multiple modeling efforts



Hanford Site 300 Area

- Fuel fabrication operations, research and development
- Liquid wastes discharged to open ponds and trenches
- Waste sites excavated and backfilled
- MNA interim ROD for uranium plume

300 Area Modeling Studies

Pacific Northwest NATIONAL LABORATORY
Proudly Operated by Battelle Since 1965

- Lindberg and Bond (1979) two-dimensional groundwater flow and transport investigation
- **DOE (1994) three-dimensional flow and transport supporting Phase I Remedial Investigation and Interim ROD**
- RESRAD simulations using uranium leaching data to determine soil cleanup levels
- Waichler and Yabusaki (2005) two-dimensional cross section investigating groundwater-river interactions
- **Meyer et al. (2007) demonstration of uncertainty methodology**
- PFLOTRAN HAMMOND
- RI/FS Model
- **Rockhold et al. (2014) system-scale model with reactive transport**

Remedial Investigation Modeling

- Analytical model not accounting for Columbia River stage variation
- Numerical model based on PORFLO3 with variable K_d
- Plume predicted to attenuate in 10 to 25 years

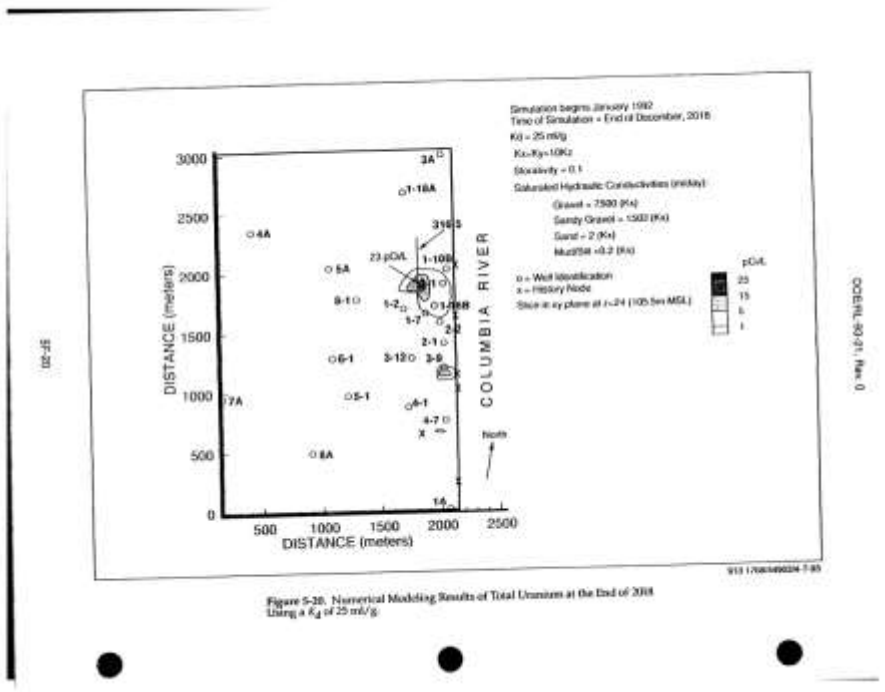


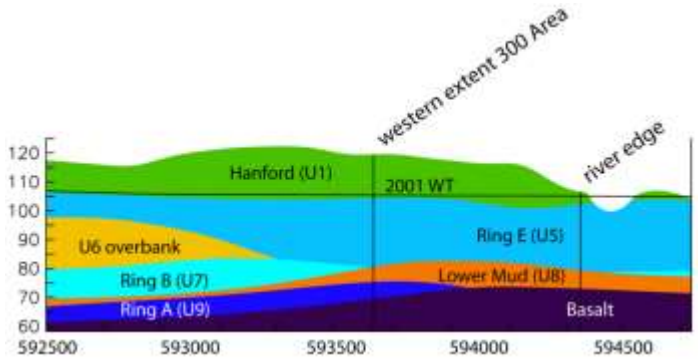
Figure 5-20. Numerical Modeling Results of Total Uranium at the End of 2018 Using a K_d of 25 mL/g

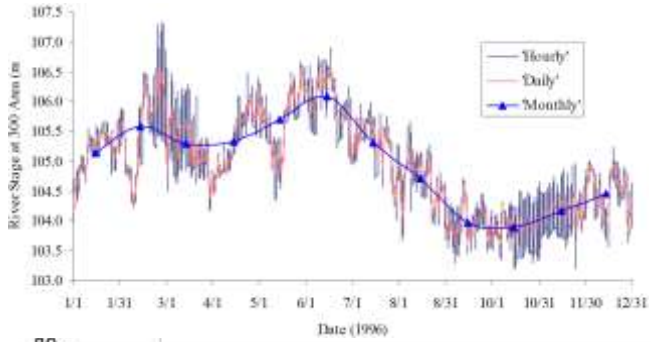
300 Area Modeling: Uncertainty Evaluation

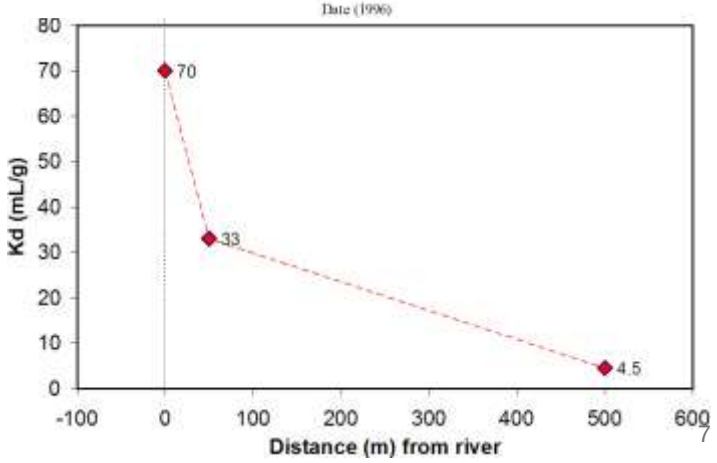
- Document a methodology for assessing hydrogeologic uncertainties in performance and dose assessment
  - Conceptual-mathematical model uncertainty
  - Parameter uncertainty
  - Uncertainty in future conditions (scenario uncertainty)
- Target to provide more realistic representation of prediction uncertainty to provide technical basis for assessments and identify gaps in site characterization and monitoring
- Sponsored by U.S. NRC Office of Nuclear Regulatory Research (NUREG/CR-6940)

Conceptual-Model Uncertainties

- Hydraulic property – homogeneous versus simple zonation
- River boundary - steady-state versus transient
- Uranium adsorption – uniform versus spatially variable (linear equilibrium assumed)
- Relative probabilities of alternative models evaluated using calibration to groundwater head and uranium concentrations

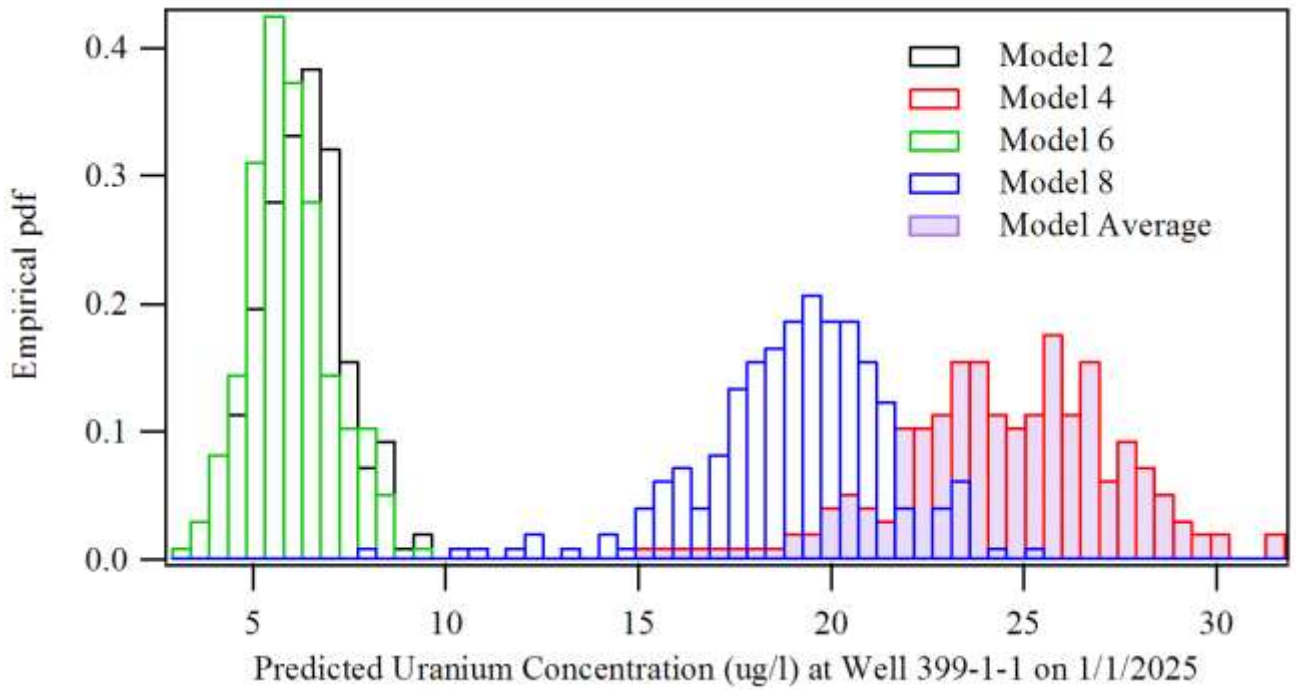






Predictive Results Including Model and Parameter Uncertainties

- In 300 Area application, Model Average = Model 4
- May be value in simulation of low-probability models
  - Predictive period conditions ≠ calibration conditions

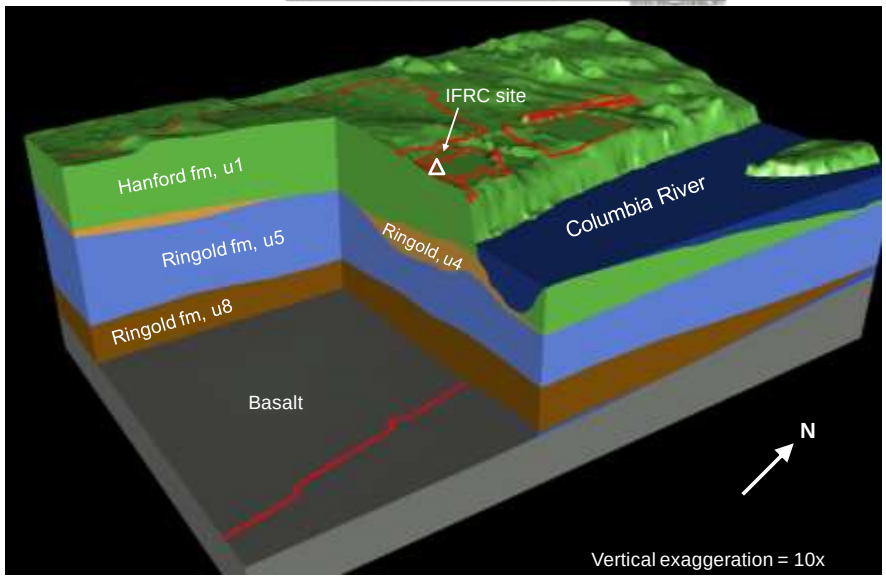


Science Investigations

- Integrated Field Research Challenge Project (IFRC)
- Laboratory and field investigations of uranium plume persistence
- Updated 300 Area conceptual model
- Funded by the DOE Office of Science, Subsurface Biogeochemical Research Program

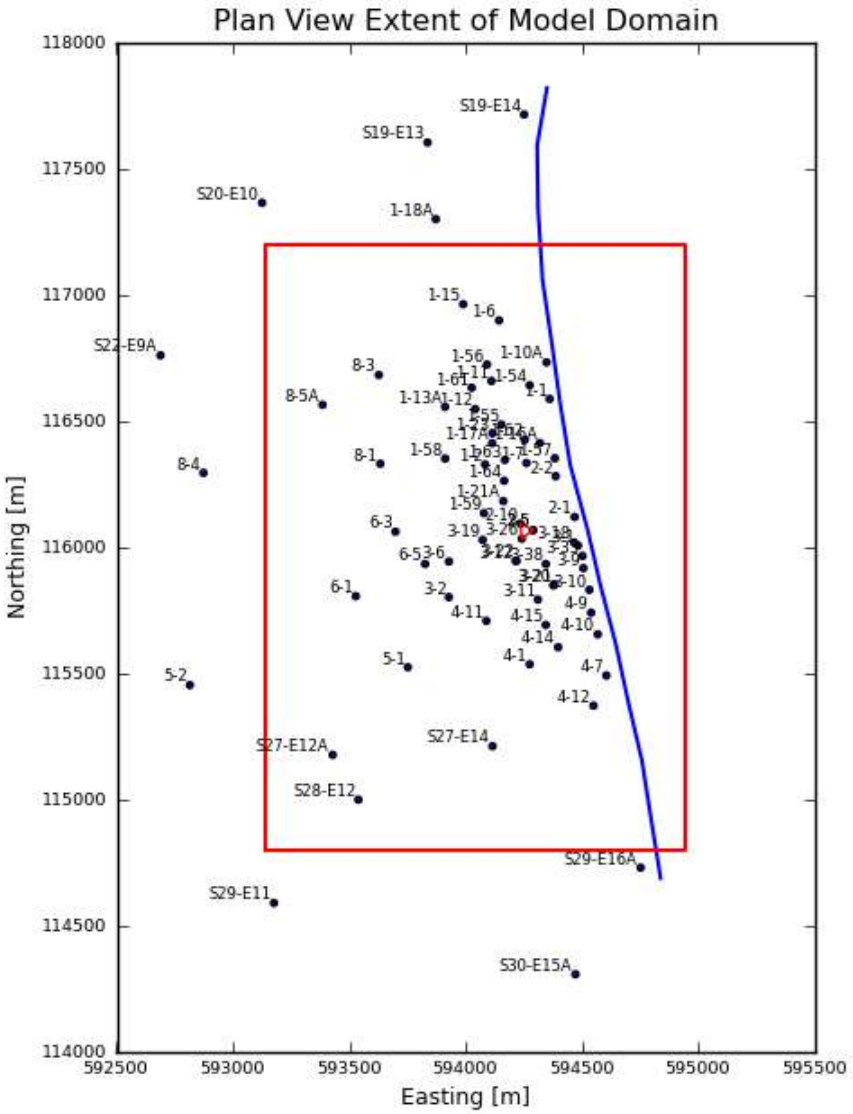
System-Scale Model

- System-scale model of Hanford 300 Area
- Decision support tool for remediation strategies and endpoints
- “System scale” refers to whole system affecting subsurface contaminant transport
- EarthVision® model of 300 Area



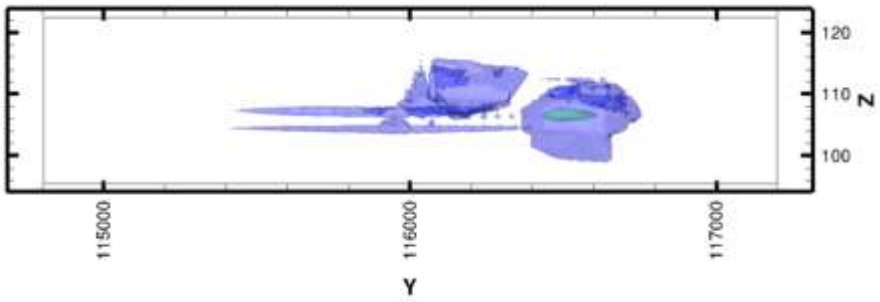
Spatial Extent and Discretization

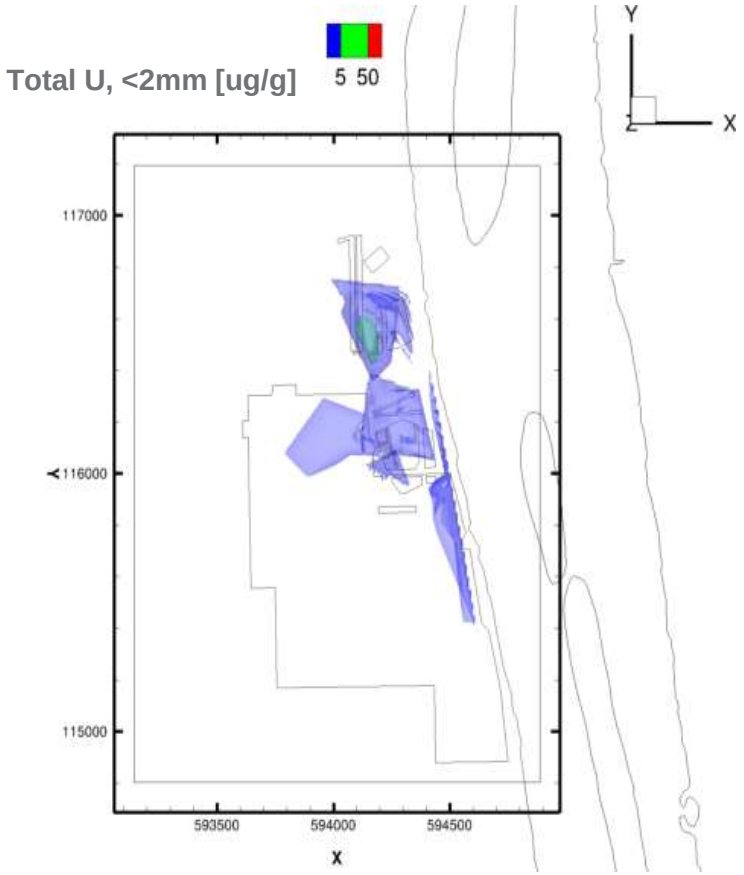
- Unconfined aquifer plus entire vadose zone
- 2400 m (N-S) x 1750 m (E-W) x 28 m (vertical)
- Uniform 10-m spacing in x-y, uniform 1-m spacing in z
- ~1.2 M total grid blocks (inactive grid blocks above ground surface and above bottom of river channel)



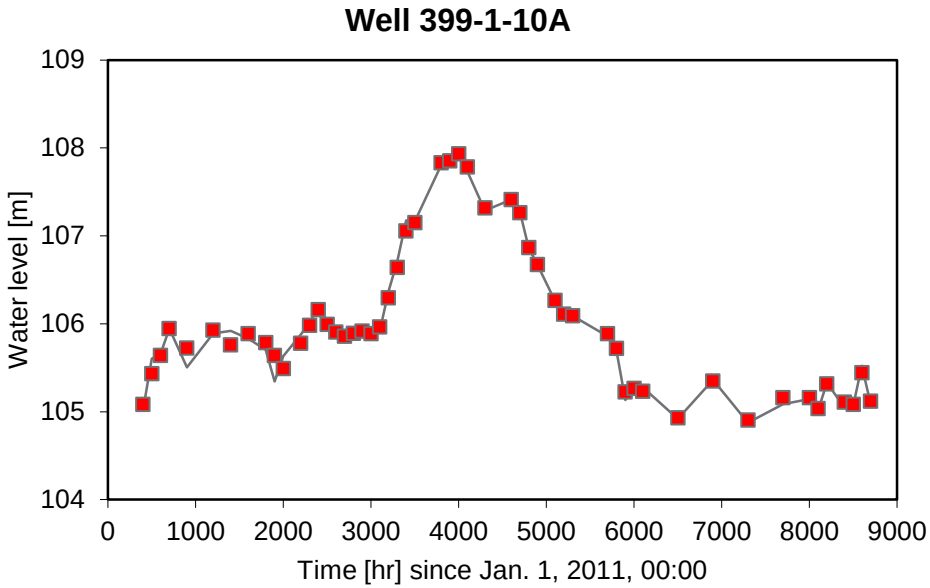
Initial Conditions

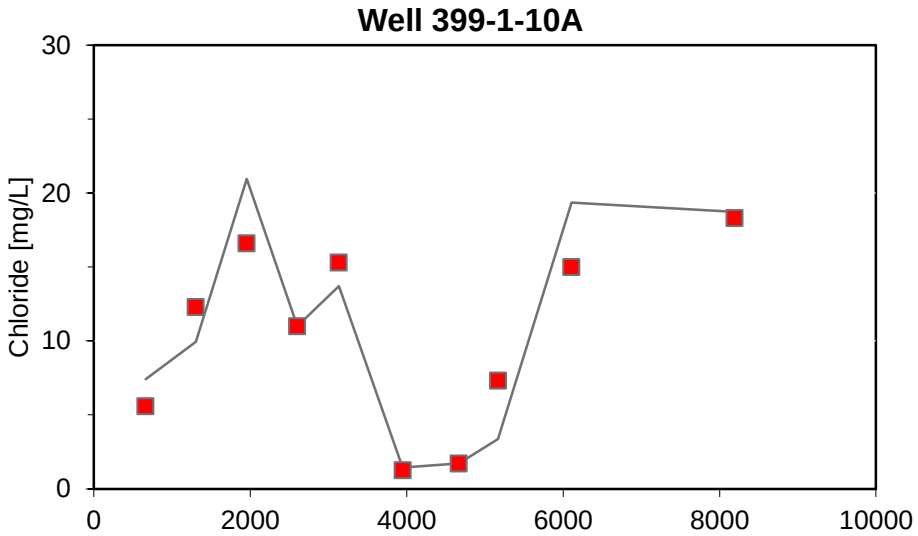
- ~ 100 kg sediment-associated U remaining after accounting for excavated/remediated sites
- Aqueous chemistry data from site monitoring (wells) and USGS (river)

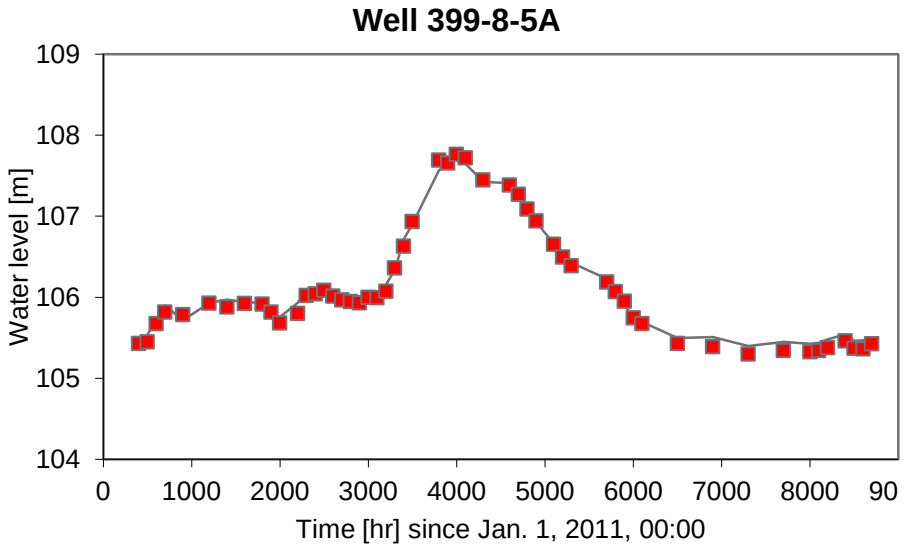


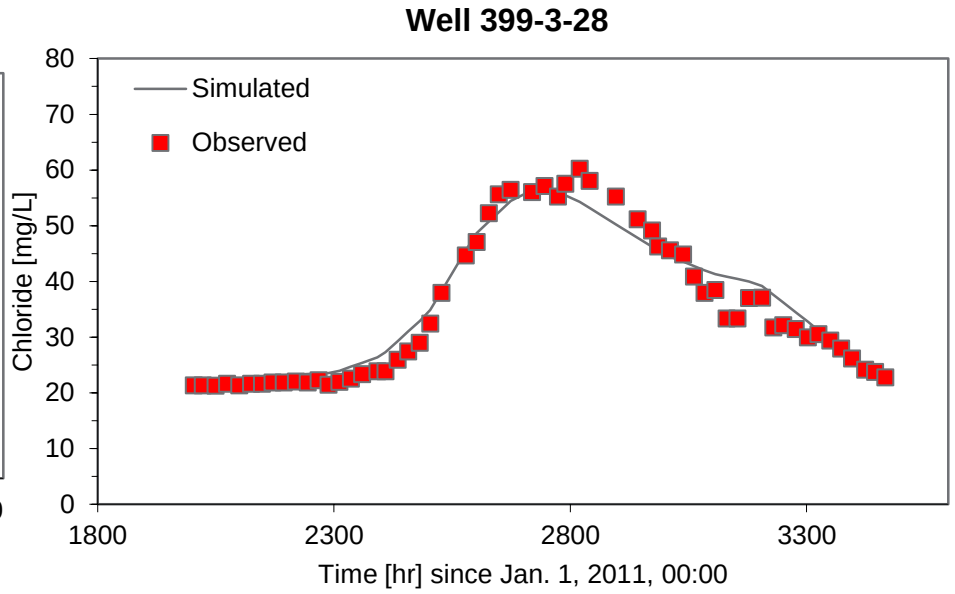


Model Calibration



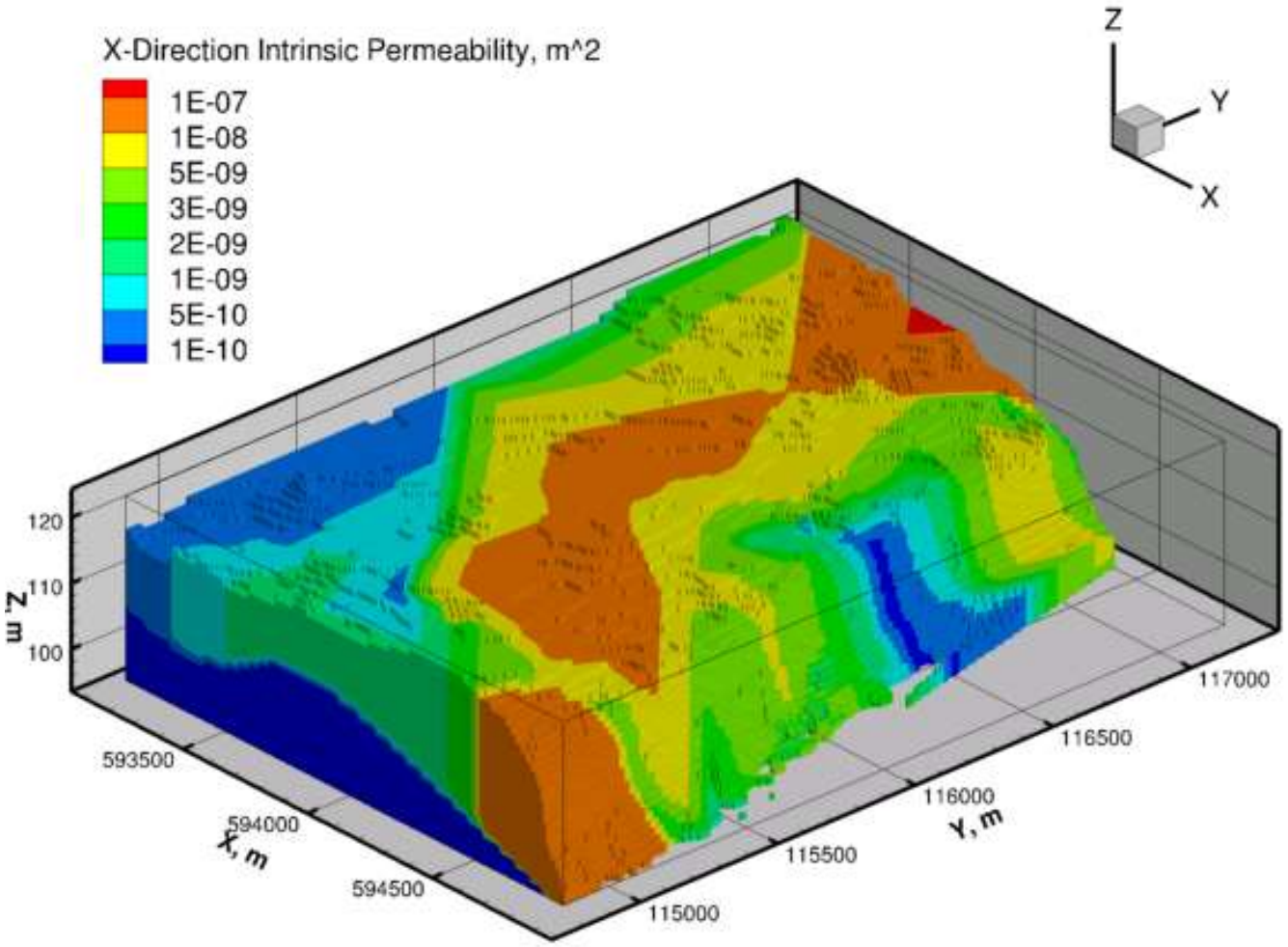




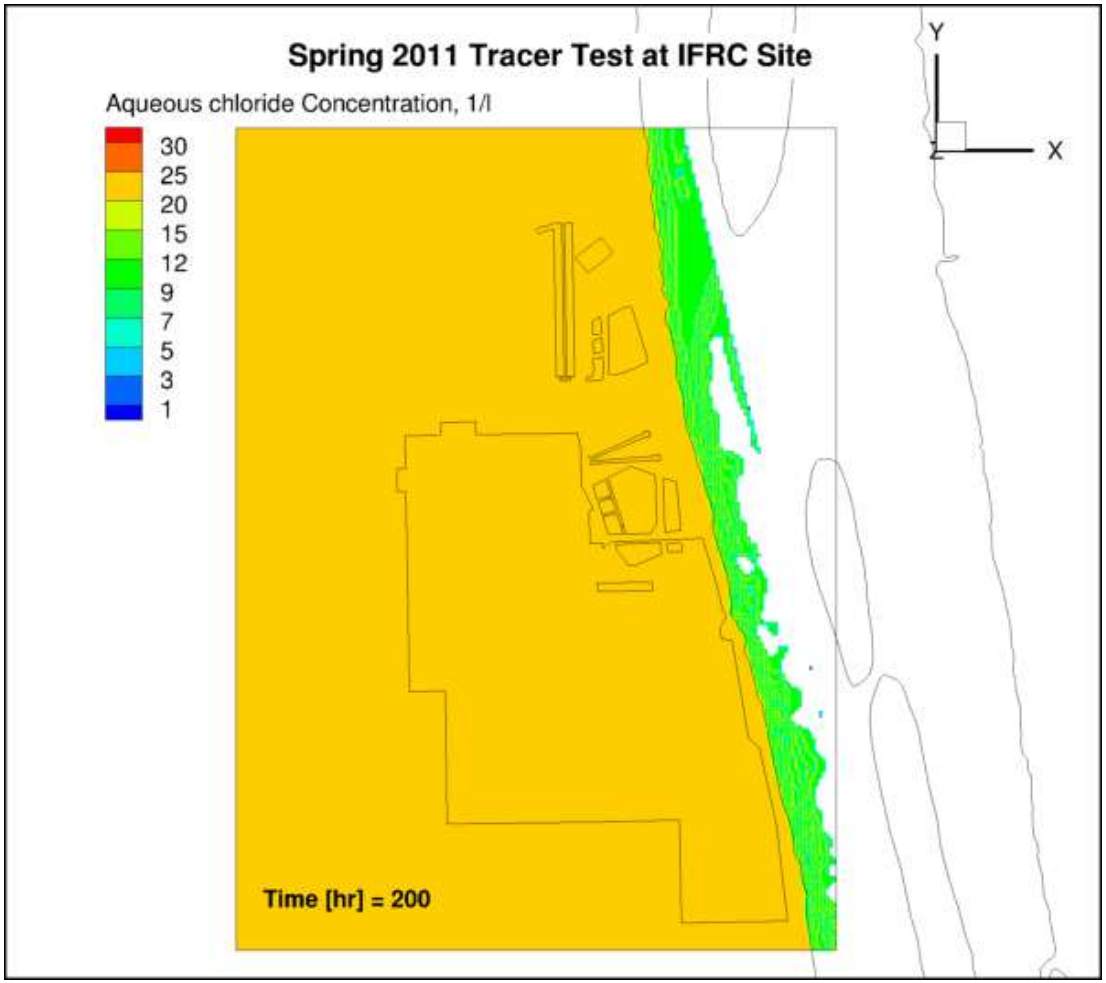


Model Calibration (cont.)

- Calibrated K field

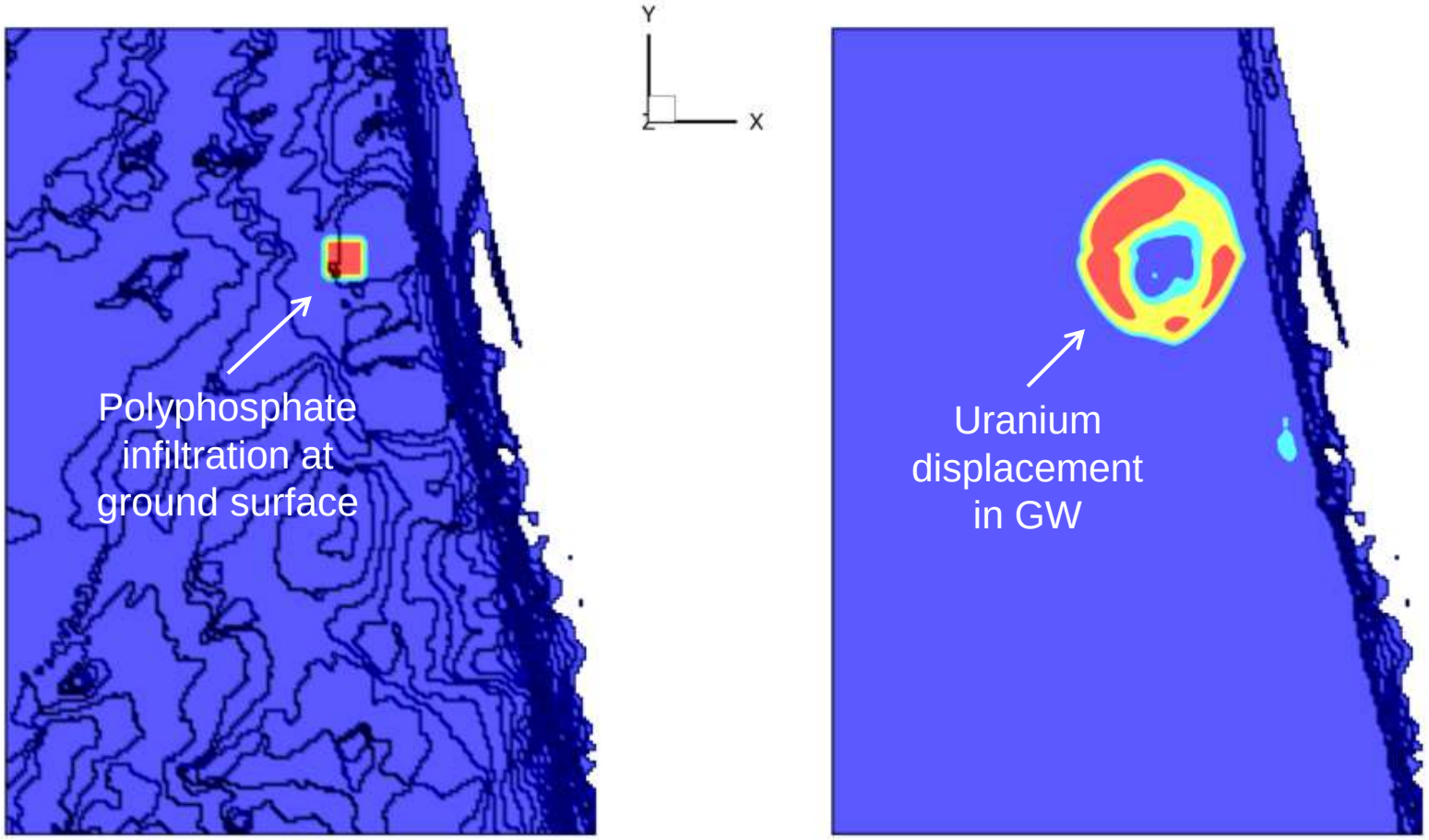


Example Simulations



Remediation Simulations

- Polyphosphate infiltration over uranium hot spot
  - After 4 days of infiltration at rate of 10 cm/hr…



Conclusions

- 300 Area modeling useful for remediation decision support, uncertainty evaluation
- Modeling assumptions need to be documented and revisted
- System-scale models can be used to synthesize and integrate historical characterization and monitoring data to provide decision support for remediation endpoints and final site disposition
- Parallel computing is critical for effective application of system-scale models

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